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# Methodological framework for urban sprawl control through sustainable planning of urban green infrastructure

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ABSTRACT

Urban sprawl is a significant challenge in urban areas and its negative influence on the quality of living confronts the scientific community, authorities, and stakeholders in identifying solutions to mitigate or minimize this trend.

Vacant lands are common in the urban landscape, particularly in sprawling cities. In this paper, we hypothesized that by increasing the attractivity of urban vacant land through urban green space development, residential development will intensify within the city boundaries, enhancing the concept of a compact city as opposed to urban sprawl and simultaneously negating urban densification. Planning new urban green spaces increases the efficiency of the urban green infrastructure and provides ecosystem services. We used analytical hierarchy processes to determine criteria to be deemed necessary when planning new urban green spaces. We also determined the suitability of 27 types of green spaces being part of an urban green infrastructure and assessed green areas recommendations for five urban zones. Finally, we identified available vacant land for potential future urban green spaces in Ploiești, Romania.

Our results have demonstrated that criteria such as biodiversity conservation, climate change regulation, and air quality improvement are to be adopted when planning new urban green spaces. Natural features are to be included, thus urban forests, transitional ecosystem, or local natural reserves are suitable in providing the desired ecosystem services in urban areas. Land availability assessments disclosed the locations and areas of presently available tracks. The proposed methodological framework provides a valuable approach to urban green space planning in the context of urban sprawl in the cities.

## 1. Introduction

As more areas of land are being urbanized, sustainability in urban planning has become a common topic within the scientific community. Researchers have proposed different models related to urban planning, such as the smart city (Neirotti et al., 2014), the compact city (Burton et al., 2003), the green city (Low, 2005) and the livable city (Girardet, 2004) to identify the best means in resolving the challenges of urban areas such as sprawl, mitigation of climate change effects or improvement of air quality (Girardet, 2004; UN Habitat, 2009). However, the question of which concept of urban planning and management is the most sustainable remains unanswered.

Social, economic, and environmental concerns have an impact on the quality of urban living (European Commission, 2013), and they are a focal point relating to the management and planning of a city (Khalil, 2012). Land is a valuable commodity for a city; it is necessary for the continuous expansion of built-up areas, which leads to urban sprawl, which specialists and planners continue to have difficulty agreeing on a definition for urban sprawl (Brueckner, 2000; Couch et al., 2007).

Despite the lack of a unanimously accepted definition of urban sprawl (Brueckner, 2000; Christiansen and Loftsgarden, 2011; Jaeger et al., 2010; Johnson, 2001), the consequences of this trend appear to be similar. Inefficient land use that occurs in sprawling cities through "… low density, scattered urban development without systematic large scale or regional planning …" (Bruegmann, 2005, page 18) tends toward increased air pollution due to long distance commutes (Nechyba and Walsh, 2004), fragmentation of natural and semi-natural areas near the urban fringe (EEA, 2006; Robinson, 2011; Shrestha et al., 2012),

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social segregation (Brueckner, 2000; Nechyba and Walsh, 2004; United Nations, 2014), loss of biodiversity (Liu et al., 2003; McKinney, 2002), and higher costs of living (EEA, 2006). Bruegmann (2005) characterizes sprawl as a persistent feature of cities throughout urban history.

Attempts to counterbalance the effects of urban sprawl lead ultimately to denser cities (Brueckner, 2000). The "compact city" model has its own shortcomings, as it predicates congested areas, reducing urban green space, and increasing the urban heat island effect (Anguluri and Narayanan, 2017; Gunawardena et al., 2017; Pearsall, 2017). Therefore, the key to decreasing urban sprawl entails a planning approach in which side-effects that adversely affect the quality of life are minimized, resulting in a compromise acceptable in mitigating the effects of both sprawl and densification of built-up areas.

To reduce city sprawl, we should first identify what promotes urban sprawl, what attracts people and real estate developers to build in the urban fringes? Land prices, societal factors, means of transportation, landscape topography, technological evolution, demographic patterns, and globalization were found to be some of the driving forces leading to urban sprawl (Brueckner, 2000; Bruegmann, 2005; Christiansen and Loftsgarden, 2011; Hennig et al., 2016; Yue et al., 2013). However, the attractiveness of suburban and metropolitan landscapes for expansion can be explained by the availability of open space and the proximity to natural and semi-natural areas or better microclimates (Bruegmann, 2005; Hennig et al., 2016; Inostroza, 2017). The challenge is consolidating these positive characteristics inside the cities while concurrently maintaining their compact pattern.

One of the many effects of urban sprawl is the increased incidence of vacant lands and abandoned buildings within the city limits (Grădinaru et al., 2017; Kremer et al., 2013; Sperandelli et al., 2013). Sperandelli et al. (2013) characterized vacant lands as land areas within urban settings without buildings, improvements, or other public uses. Vacant lands resulting from sprawl and a decrease in population growth rates (Nassauer and Raskin, 2014) are considered problems by local authorities because of their contribution to the promotion of unlawful activities, crime, and violence (Kremer et al., 2013; Sanches and Pellegrino, 2016), resulting in negative spaces in the urban landscape (Kim et al., 2015). Researchers have emphasized the positive attributes generated by vacant land that includes provisions of ecosystem services (Kim et al., 2015; McPhearson et al., 2013), social and environmental justice (Pearsall, 2017), and the potential for urban green space development (Sanches and Pellegrino, 2016), considering them a subsequent resource for contemporary cities encountering complex challenges.

In this paper, we theorize that properly managed vacant lands may be transformed from an urban dilemma into a viable resource, minimizing the negative effects of sprawl and densification. To achieve this stage, vacant lands must be transformed and rendered appealing for residents and real estate developers. Residents will then prefer to live within city limits (Arnberger and Eder, 2012) and real estate developers would equally prefer to build closer to the business center as these properties would then have a higher monetary value (Anguluri and Narayanan, 2017).

Planning new urban green space (UGSs) may be a solution to enhance the attractiveness of these sites and promote the viability of a city. According to Breuste et al. (2013), UGSs encompass a range of natural or artificial areas covered by vegetation (e.g., parks, street trees, and residential lawns) that effectively increase the quality of life by providing recreational benefits (Kabisch and Haase, 2014) and mitigating environmental issues associated with urban areas (Derkzen et al., 2017; Gill et al., 2007; Gunawardena et al., 2017; Lafortezza et al., 2013). Sprawl causes fragmentation of natural and semi-natural areas in the urban fringe (Inostroza et al., 2010, 2013), and urban densification decreases the area covered by UGSs within a city (Haaland and van den Bosch, 2015); therefore, irrespective of planning approach, the reduction of land areas covered by vegetation near and within urban areas represents a major challenge.

However, it is inadequate just to "green" the vacant lands and transform them into desirable parcels (Sanches and Pellegrino, 2016). Badiu et al. (2016) concludes that regulations that establish thresholds for UGS coverage in cities are inadequate to attain sustainability and that urban-specific characteristics should be incorporated when planning new UGSs. Additionally, the proximity of UGSs is an important variable as Nechyba and Walsh (2004) reported in that the perception of individuals living near open spaces or green areas is highly valued but that perception decays noticeably as distance to the UGSs increases. A brief conclusion on selecting a proper UGS site is given by Votsis (2017), who emphasized that the greening of cities is an open-ended goal and that the chosen location must be taken into consideration as to which UGS is best suited for that location, and what are the benefits expected from the UGS. Therefore, planning new UGSs within a city, using existing vacant lands, embodies a matter of suitability

In this paper, we consider urban functional zones (UFZs) as the urban component in relation with which the UGSs should be planned accordingly. The reasoning behind this perspective lies in the findings of Sun et al. (2013), which characterized the UFZ as the basic component of urban planning and which represents a compact urban area of similar social and economic function (e.g., industrial areas, residential areas, and commercial areas). If we are to decide that a portion of the vacant lands within a city should be covered by UGSs to increase their attractiveness for development as a response to urban sprawl, and concurrently mitigate the negative effects specific to compact cities, such as urban heat islands, we must do this in accordance with nearby UFZs.

Efficient UGS planning within a city, using available vacant lands may lead to the development of natural and semi-natural land networks that connect the UGSs within the city with the natural and semi-natural landscape on its periphery, defining what several researchers characterize as Urban Green Infrastructure (UGI) (Davies et al., 2015; Derkzen et al., 2017; Mell, 2008). The UGI model lacks unanimously accepted characterization (Davies et al., 2015, 2006; Horwood, 2011; Lafortezza et al., 2013), but it represents a common topic of urban sustainability. In this paper, we will consider UGI as a network of vegetated land areas, functionally connected with the natural and semi-natural areas on the periphery of the urban area.

Our study is based on the hypothesis that by increasing the attractiveness of urban vacant land through UGS planning, development will expand within the city limits, enhancing the model of a compact city as an alternative to urban sprawl and concurrently mitigating the negative effects of urban densification. In this paper, we propose a methodological framework based on an analytical hierarchy process (AHP), aiming to 1) assess which UGS are the most suitable to be included in a UGI, 2) designate proper UGSs fitting the characteristic and environmental factors of UFZs, and 3) determine the availability of vacant lands for planning new UGSs in a Romanian medium-size city.

## 2. Methods

### 2.1. Study area

Romania's present urban planning follows the same paths of former socialist countries with the re-establishment of private property rights and the shift to a free market economy (Stanilov, 2007b). Population growth changes consumption patterns with citizens preferring individual residential dwellings to collective units (Pătroescu et al., 2009; Stanilov, 2007a), owning private cars (Suditu, 2009), and shopping in retail units (Hirt, 2009; Nae and Turnock, 2011). To fulfil these demands, land is needed to develop new residential areas and wider commercial zones.

In a study by Suditu et al. (2010), the authors allege that urban sprawl can be precisely dated in Romania, beginning with the first law ruling in 1991 allowing private land ownership and individuals to recover lands they owned prior to the communist regime. The authors

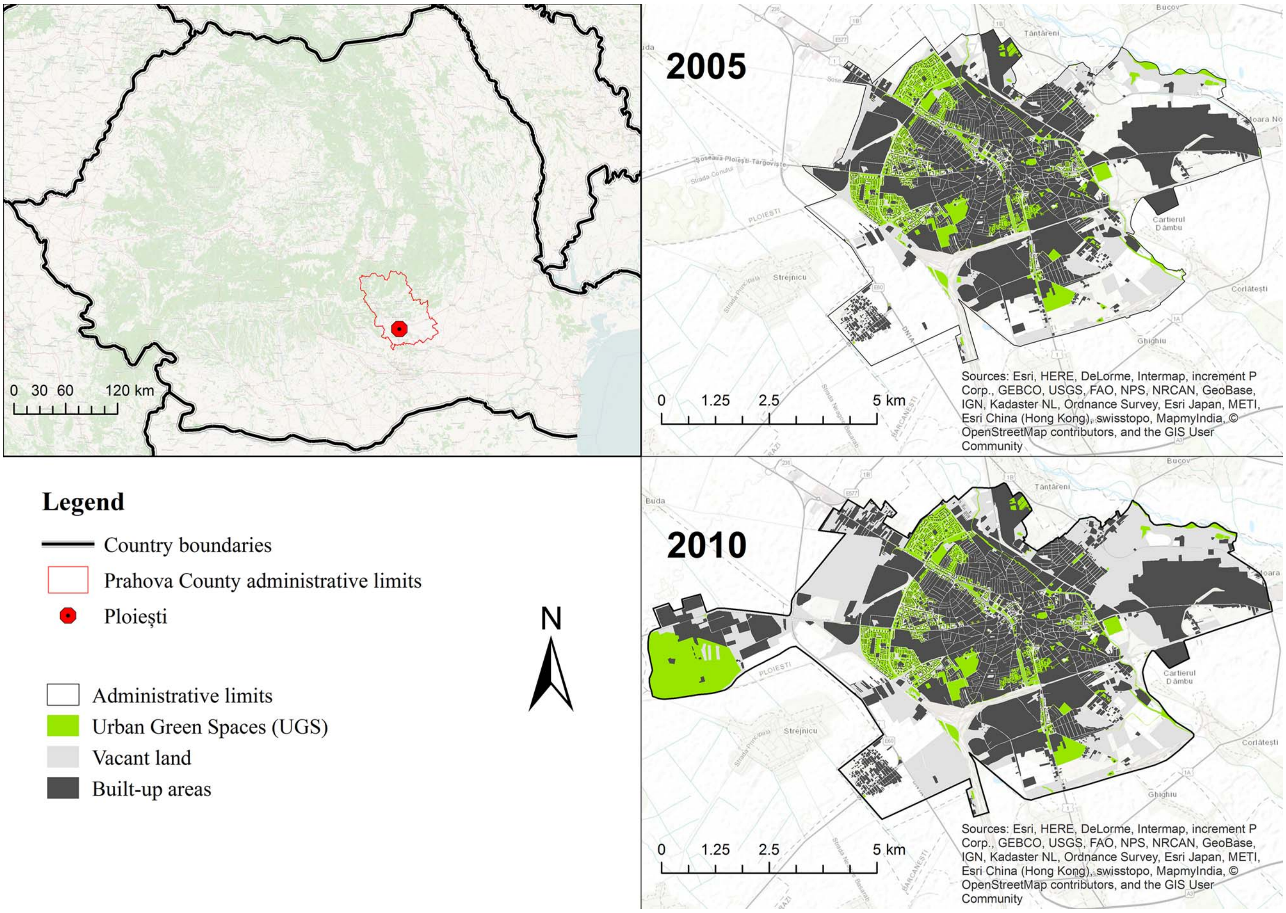



**Fig. 1.** Comparative analysis of land use within the study areabetween 2005 and 2010.

also concluded that 86% of Romanian cities were confronting urban sprawl, particularly medium- and metropolitan-sized cities.

As a case study, for our analysis, we have selected Ploieşti, a traditionally industrial city specializing in oil exploration and processing and situated in Prahova County [Fig. 1]. Its sprawling penchants were documented by Gavrilidis et al. (2015). In 1989, with the end of communism, most of the cities confronted deterioration with many industrial sites being replaced with commercial enterprises or residences or were designated as brownfields (Loures, 2015). Ploieşti's case was atypical because the oil processing sites were rapidly bought by global oil enterprises and the economic growth of the city continued even during the coming transition years. From 1990 to 2005, more than 20% of the natural and semi-natural land was transformed and developed (Gavrilidis et al., 2015). In 2010, more than 41% of the city's total area was encompassed by developments and 11% by public green areas. The vacant lands identified in 2010 enclosed 24% of the total city area [Table 1].

Ploieşti is a medium-sized city and the county's capital. The city faces the problem of urban sprawl where the presence of vacant lands is increasing and lacks areas covered by UGSs. Our proposed methodological approach addresses cities with similar characteristics.

### 2.2. UGS selection

It is not enough to randomly plan UGSs to increase the percentage of UGS coverage in an urban area (Badiu et al., 2016; Gill et al., 2007; Kabisch and Haase, 2014). For a UGS to provide the requisite ecosystem services, it must satisfy certain criteria (Van Herzele and Wiedemann, 2003). After researching the scientific literature that addresses UGS planning, we identified nine criteria to be considered before planning the expansion of UGSs in an urban area [Table 2].

We ranked the nine criteria using the AHP model based on expert opinion (Iojă et al., 2014; Onose et al., 2015; Yin et al., 2016). The AHP model was conducted applying the Delphi method (Di Zio et al., 2017) and the opinion of seven experts working in research or higher education in the fields of geography, urban planning, environmental impact assessment, biology, landscape ecology, green infrastructure planning, and remote sensing analysis.

We selected 27 examples of UGSs, chosen from those proposed by Cvejić et al. (2015) and Dige (2011) [Appendix 1 in Supplementary material], for our analysis. The chosen examples encompass the geographical setting of Ploiesti, and comply with typologies of UGSs encountered in Romania. We then asked the same professionals to assign expert scores (Es), applying a scale of from 1 to 5 as exemplified in [Table 2], to rank the 27 UGSs based on their capacity to achieve the nine criteria. Es were multiplied by criteria weights (w) resulting from the AHP analysis, resulting in nine criterion scores (Cs) for each of the 27 UGSs as follows:

$$Cs = Es \times w$$

For the UGS ranking we generated suitability scores (SuS) for each by calculating the average Cs for every UGS as follows:

$$SuS = \sum Cs/9$$

The SuS values highlight whether a UGS is suitable to be part of a UGI model based on the nine selected criteria and their respective weights established through AHP analysis.

**Table 1**
Land use dynamics and statistics for Ploieşti between 2005 and 2010.

| Category | Land use | Data source | Area (ha) | | Percent change[1] % | Difference |
|---|---|---|---|---|---|---|
| | | | 2005 | 2010 | | |
| Constructed areas | commercial buildings; individual housing; industrial buildings; institutional buildings; multi-family dwelling housing; places of worship | aerial imagery from 2005 and 2010 | 2229.71 | 2500.04 | −2.0 | −270.32 |
| Green areas | public green spaces; graveyards; meadows; sporting facilities; water bodies | aerial imagery from 2005 and 2010 | 453.48 | 691.70 | 2.6 | 238.22 |
| Agricultural land | land covered constantly with crops | aerial imagery from 2005 and 2010 | 1293.82 | 807.85 | −11.8 | −485.97 |
| Vacant land | former agricultural land that has been abandoned; land that were occupied with building prior to their demolition | aerial imagery from 2005 and 2010 | 582.16 | 1452.46 | 12.7 | 870.29 |
| Total city area | | INS[2] | 5140.66 | 6047.84 | | 907.17 |
| | | | Inhabitants | | | |
| Population | | INS[2] | 232527 | 209945 | | −22582 |
| | | | $m^2$ | | | |
| Green space per capita | | | 19.50 | 32.94 | | 13.44 |

[1] Relative to the total official administrative area.
[2] INS – National Institute of Statistics.

**Table 2**
Criteria selection for assessing the UGS suitability for planning an efficient UGI.

| Criteria | Explanation | Reference | Score explanation |
|---|---|---|---|
| Management costs (man) | Expenses required to maintain the UGS at a proper level of quality. | Management is an important aspect in due to the low amount of funding allocated by public authorities for UGS (Iojă, Rozylowicz et al. 2011) | 1–very high costs – 5 – very low costs |
| Ease of construction (bld) | It requires a long time to build and excessive costs to build, or it requires a large amount of land and complicated bureaucratic procedures to start building the UGS | Investments in UGS is not a priority for local authorities as other type of land uses prove to be more profitable (Heynen, Perkins et al. 2006; Vandermeulen, Verspecht et al. 2011) | 1 – very hard – 5 – very easy |
| Acceptance (acc) | How accepted the UGS is in Romania and if there are examples of the UGS component in Romania | Local decision makers usually follow a known pattern when planning UGS for their cities (Cicea and Pirlogea, 2011) | 1 – very low acceptance – 5 – very popular |
| Efficiency in combatting climate change (cce) | Is the UGS efficient in response to climate change issues? | Global climate change and urban air quality represent important environmental issues, and many studies and public reports have emphasized the role of UGS in combatting these issues (Carter, 2011; EEA, 2012) | 1 – very low efficiency – 5 – very efficient |
| Air quality improvement efficiency (aqi) | Is the UGS efficient in improving the local air quality? | | 1 – very low efficiency – 5 – very efficient |
| Income generation (ige) | Whether the UGS can generate income for the local authorities or for a private actor | Most local authorities avoid developing UGS as it doesn't generate direct income for the local budget (Sýkora and Ourednek, 2007) | 1 – very low profitability – 5 – very profitable |
| Biodiversity benefits and conservation (bdb) | Whether the UGS contributes at improving biodiversity conservation levels | Biodiversity is a critical issue due to the vulnerability of species to extinction, and the need to create urban areas habitable for plants and animals represents a challenge (Hostetler et al. 2011) | 1 – very low benefits – 5 – very high benefits |
| Social network stimulation (sns) | Whether the UGS stimulates outdoor activities and thereby human interaction | UGS, especially large ones such as parks or urban forests, make great contributions to social inclusion and networking, combating segregation and bringing together in one place people from different social categories, religions or ethnicities (Thompson et al., 2013) | 1 – very low stimulation – 5 – very high stimulation |
| Specificity (spf) | Whether the UGS can be built or managed only in specific cases (depending on natural or cultural conditions) or if it can be built or managed independent of circumstances | Some UGS are strictly dependent on natural characteristics (Pulighe, Fava et al. 2016) | 1 – very specific – 5 – very general |

### 2.3. UGS recommendation

As theorized, planning UGSs on vacant lands within a city will attract real estate investments, and these UGSs would strengthen that probability. We identified UFZs near available vacant lands (Panduro and Veie 2013). We selected five UFZs that are specific to Ploieşti: industrial, commercial, multi-dwelling housing, individual housing, and agricultural areas. To determine which UGSs are compatible with the UFZs, we asked the professionals to rank the 27 UGSs by assigning scores ranging from 0 to 5 for each [Table 3]. The analysis continued with the calculation of recommendation scores (Rs) for each of the 27 UGSs in relation to the five UFZs, as is described in [Table 3].

### 2.4. Vacant land availability assessment

The final step of our methodological framework consists of identifying the nearest available vacant land of the selected UFZ. It is not cost-effective to propose all vacant lands be encompassed as UGS, we therefore aimed in selecting areas within a maximum of 100 m from a UFZ. The assessment of vacant land availability was not limited only to the areas bordering the functional zones, it also included areas within the functional zones as well. Therefore, we extracted, using ArcMap 10.2 and aerial images (resolution −1:5000, issued 2010), the features of each UFZ, the vacant lands, and the exiting UGS. We established buffer zones for the UFZ features of 10 m, 50 m and 100 m. Afterwards, we converted the vector features representing the buffer areas surrounding the UFZ features and the vacant lands into raster files of three different pixel sizes (0.01 ha, 0.25 ha and 1 ha). In this manner, later, we will be able to identify whether wider or narrower UGSs could be planned. We overlapped the buffer areas of the vacant lands accordingly by matching pixel sizes and the vacant lands placed within 10 m, 50 m and 100 m from the UFZ features occurring within. To eliminate errors and to enhance the

**Table 3**
Recommendation score (Rs) algorithm.

| URBAN FUNCTIONAL ZONE | UGS |
|---|---|
| | Scale:<br>0 (not recommended) 1 (acceptable) 2 (slightly recommended) 3 (fairly recommended) 4 (recommended) 5 (highly recommended) |
| | Calculating recommendation score (Rs) for one UGS: |
| | $Rs = \sum s/n * SuS$<br>s = expert scores<br>n = number of experts<br>SuS = Suitability scores |

accuracy of the generated maps we converted the new resulting raster files into vectors to facilitate geometric operation, allowing us to erase certain features that were coincidental with other urban features, further allowing us to highlight the precise amount of available vacant land. A schematic representation of the vacant land assessment process is presented in [Appendix 2 in Supplementary material].

## 3. Results

### 3.1. UGS selection

The results of the AHP analysis indicates that, according to expert ratings, the most important criteria to consider when planning a UGS are biodiversity benefits and conservation (score: 0.21), followed by efficiency in combatting climate change (score: 0.19) and air quality improvement efficiency (score: 0.18). Of lesser criteria to consider, the lowest scores were those of income generation (score: 0.05) and acceptance of the infrastructure in Romania (score: 0.03) [Table 4].

The SuS attributed to the selected UGS ranged between 0.259 and 0.448, the highest values being recorded by urban forests (score: 0.448), urban parks or public gardens (score: 0.424), watershed forests (score: 0.409), and local nature reserves (score: 0.408). The lowest values of the SuS were recorded by restored areas that were previously fragmented or degraded natural areas (score: 0.299), individual trees (score: 0.298), sustainable urban drainage (score 0.293), squares with grass and flowers (score: 0.289), grass squares (score: 0.270) and flower pots (score 0.259). The maximum SuS for a UGS component was 0.556, and the average score of all UGS was 0.338, meaning that the average suitability for all UGS was 60.93% [Table 5].

### 3.2. UGS recommendation

The Rs values ranged from 0 to 2.12. Because the Rs for each UGS was determined based on SuS, the maximum grade that could be scored differed among the UGSs [Fig. 2]. We emphasized the top five UGSs according to the Rs values in relation to each UFZ. The highest value was received by urban parks associated with multi-dwelling housing [Table 6]. The most highly recommended UGS for all five functional zones were street trees, protection forests, singular trees, urban parks, and sustainable urban drainage.

**Table 4**
Criteria weight values – see also again [Table 2].

| Criteria | Acronym | Weight |
|---|---|---|
| Biodiversity benefits and conservation | bdb | 0.21 |
| Climate change combat efficiency | cce | 0.19 |
| Air quality improvement efficiency | aqi | 0.18 |
| Building easiness | bld | 0.09 |
| Social network stimulation | sns | 0.09 |
| Management costs | man | 0.08 |
| Specificity | spf | 0.08 |
| Economic profitability | epr | 0.05 |
| Popularity of the infrastructure in Romania | pop | 0.03 |

**Table 5**
SuS values for the selected UGS (converted in percentages).

| 40–50% | 50–60% | 60–70% | 70–80% | 80–90% |
|---|---|---|---|---|
| Flower pots; Grass squares. | Squares with grass and flowers; Sustainable urban drainage; Singular trees; Restored areas which were previously fragmented or degraded natural areas; Ponds for fishing; Hedgerows; Eco-ducts; Biodiversity tunnels; Bogs; Green roofs; Vertical gardens; Orchards; Allotment gardens; Riparian river vegetation. | Street trees; Farmlands with high natural value; Pastures; Small woodlands; Transitional ecosystems between cropland, grassland and forests; Rivers and floodplains. | Protection forests; Local nature reserves; Watershed forests; Urban parks or public gardens; | Urban forest |

#### 3.2.1. Vacant land availability

We calculated the overall vacant land availability for compact patches (pixel sizes) of 100 $m^2$, 2500 $m^2$ and 10000 $m^2$ [Table 7]. Some vacant lands were shared by two or more functional zones depending on the buffer size [Fig. 3].

Compact land patches of 100 $m^2$ (pixel size 10 × 10 m) recorded more land surface within the same buffers than the analysis including compact land patches of 0.25 ha and 1 ha. The distribution of contiguous available vacant land reveals that the peripheral areas of the city have more potential to be planned as UGS. An example of this situation is shown in [Fig. 4] which emphasizes the maximum contiguous available vacant land using compact land patches of 100 $m^2$ within a 100-m buffer.

In addition to the location of contiguous available vacant land, the amount of patches and their areas is equally important as they can be merged with the Rs as shown in [Fig. 5], where we emphasize the amount and surfaces of contiguous available vacant land within 100 m of a UFZ.

## 4. Discussion

The proposed methodological framework assesses what model of UGS is best planned on available vacant lands in relation to a city's UFZs. In accordance with the findings of Nechyba and Walsh (2004), Mell (2008), and Panduro and Veie (2013), we emphasize that neighbouring land, UFZs in our case, cannot be dismissed when planning new UGSs, forming the basis for the outcome of this paper. The designation of available vacant land for UGS planning through an all-inclusive map

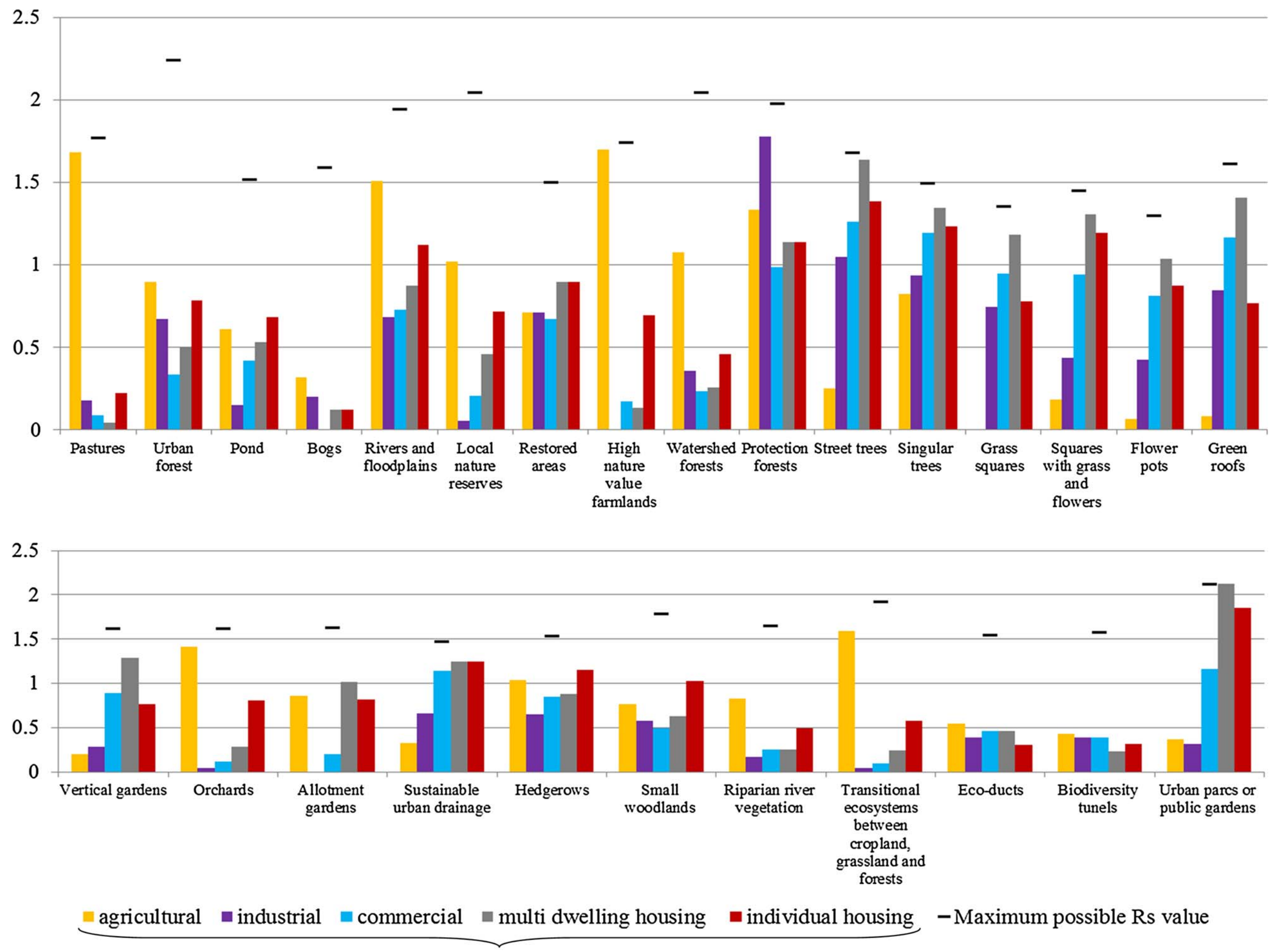



**Fig. 2.** Rs scores of the 27 UGSs in relation with all five UFZs.

is the second major outcome. A complete image of the available vacant land would assist urban planners and decision makers in planning new UGSs that, in turn, could relate to the existing UGSs and natural and semi-natural areas of the urban periphery, establishing an efficient UGI. These outcomes can provide decision makers and urban planners a clear perspective of urban vacant lands and they can use them as a resource in encouraging real-estate developers to build within the city limits rather than on its outskirts.

The AHP states that a UGS should be efficient regarding biodiversity conservation, climate change resilience, and air quality improvement. The results reinforce the findings of other researchers regarding the relevance of the UGI concept in climate change regulation (Anguluri and Narayanan, 2017; Derkzen et al., 2017; Gill et al., 2007), biodiversity conservation (Andersson et al., 2014; Hostetler et al., 2011; Kabisch, 2015) and air quality improvements (Bottalico et al., 2016; Morakinyo et al., 2016). Criteria of building ease and management costs were assigned lower weights, ranking 4th and 6th, respectively. However, Hostetler et al. (2011) acknowledged that creating green infrastructure is insufficient, that it should be managed properly to provide continual ecosystem services. The AHP analysis based on expert

**Table 6**
Top 5 UGS according to their Rs scores for each UFZ.

| UFZ | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Agricultural areas | | | Industrial area | | | Commercial areas | | | Multi-dwelling housing | | | Single dwelling housing | | |
| UGI comp | Rs | Max Rs | UGI comp | Rs | Max Rs | UGI comp | Rs | Max Rs | UGI comp | Rs | Max Rs | UGI comp | Rs | Max Rs |
| High nature value farmlands | 1.70 | 1.74 | Protection forests | 1.78 | 1.98 | Street trees | 1.26 | 1.68 | Urban parks or public gardens | 2.12 | 2.12 | Urban parks or public gardens | 1.86 | 2.12 |
| Pastures | 1.68 | 1.77 | Street trees | 1.05 | 1.68 | Singular trees | 1.19 | 1.49 | Street trees | 1.64 | 1.68 | Street trees | 1.38 | 1.68 |
| Transitional ecosystems | 1.59 | 1.92 | Singular trees | 0.93 | 1.49 | Green roofs | 1.17 | 1.61 | Green roofs | 1.41 | 1.61 | Sustainable urban drainage | 1.25 | 1.47 |
| Rivers and floodplains | 1.51 | 1.94 | Green roofs | 0.85 | 1.61 | Urban parks or public gardens | 1.17 | 2.12 | Singular trees | 1.34 | 1.49 | Singular trees | 1.23 | 1.49 |
| Orchards | 1.41 | 1.62 | Grass squares | 0.74 | 1.35 | Sustainable urban drainage | 1.14 | 1.47 | Squares with grass and flowers | 1.30 | 1.45 | Squares with grass and flowers | 1.20 | 1.45 |

**Table 7**
Different available areas for future planning of UGS within the selected buffers.

| Patch size ($m^2$) | Buffer (m) | Available land areas for UGS planning (ha) | | | | | Total available area (ha) | Total existing UGS area (ha) |
|---|---|---|---|---|---|---|---|---|
| | | Agricultural areas | Industrial areas | Commercial areas | Multi-dwelling housing | Single dwelling housing | | |
| 100 | 10 | 33.9 | 42.4 | 3.5 | 4.7 | 32 | 113.1 | 139.4 |
| | 50 | 182.6 | 209.3 | 20.9 | 20.1 | 129.2 | 489.2 | 316.7 |
| | 100 | 332.9 | 358.8 | 45.5 | 34.9 | 218.2 | 772 | 383.1 |
| 2500 | 50 | 151 | 176.9 | 17.7 | 15.1 | 100.8 | 414.9 | 246.2 |
| | 100 | 299.7 | 320.3 | 41.9 | 26.7 | 156.6 | 698 | 307.8 |
| 10000 | 100 | 264.2 | 283 | 41.7 | 18 | 145.8 | 617.8 | 259.2 |

opinion is usually biased because of the experts' knowledge in a specific research domain. These findings demonstrate limitations in the studies and necessitate further analysis in order to include any perception of the relevant authorities and populations, as they are the main managers and users of an UGS.

The suitability assessment revealed that, in accordance with the AHP analysis, the most suited UGS for a city is an urban forest. This was a predictable outcome, as many studies emphasized the benefits of urban forests in improving air quality (Bottalico et al., 2016), higher health levels and leisure time (Zhang et al., 2013), and biodiversity characteristics, particularly in the connection between people and nature (Kabisch, 2015). According to many researchers, urban forests provide the most complex ecosystem services in urban settlements (Dobbs et al., 2014); thus, they should contribute an important component to UGI, considering the pressures and threats that existing urban forests are subject to in urbanized areas (Salvati et al., 2017). UGSs, such as protected forests, local nature reserves, watershed forests, or urban parks or gardens, ranked high based on their *SuS* values, consolidating the findings emphasizing the positive role of nature-based solutions in urban areas (Nesshöver et al., 2017).

The selection of the best UGSs for five different UFZs of the city demonstrated the differences that exist in different urban environments. UFZs not only differ specifically in size, type, complexity and structure (Sun et al., 2013; Yin et al., 2016; Zhang and Du, 2015) but also in management of their locations. Each UFZ has a different requirement regarding the expected ecosystem services and different impacts on the general urban ecosystem (Sun et al., 2013). The *Rs* values indicated that sustainable agricultural methods must be planned accordingly and within or in the proximity of agricultural areas. The development of highly natural farmlands is considered a key component in increasing the sustainability of urban areas (La Rosa et al., 2014) and that approach is included in the European Union's strategies regarding sustainable farming (Keenleyside et al., 2014). The positioning of agricultural areas near urban settlements provides a higher degree of ecosystem services (Huang et al., 2015; Wood et al., 2015), but to enhance these, farming methods should include sustainability principles.

For industrial areas, *Rs* values indicate that the best UGSs to contemplate are protection forests, street trees, or singular trees. It is acknowledged through studies that these factors improve air quality by absorbing pollutants (Baró et al., 2014; Nowak et al., 2013) and reducing noise pollution (Das, 2016; Patel et al., 2014).

Chiesura (2004) concludes that people in contact with nature in urban areas experience positive feelings and additional beneficial services. The *Rs* values for residential areas demonstrate that urban parks or public gardens are best suited if positioned in their vicinities. These findings are in concert with findings stating that urban parks or public gardens improve health levels (Tzoulas et al., 2007; Wolch et al., 2014), encourage physical activities (Koohsari et al., 2015; McCormack et al., 2014), encourage social interaction (Dinnie et al., 2013), improve the landscape (Gavrilidis et al., 2016), and foster the quality of living (Thompson et al., 2013). Residential areas benefit due to the high accessibility levels of UGSs.

Vacant land availability assessment aims to identify available areas to include UGSs that are nearer to UFZs and large enough to support all forms of green space. The use of buffer areas is similar to the approach of Kabisch and Haase (2014), whose analysis assessed accessibility to urban parks, or that of Van Herzele and Wiedemann (2003), who developed a monitoring tool for the accessibility and appeal of UGSs.

Extending public UGSs into areas that are avoided by nearby residents and real estate developers encourages new investments in these areas and further decreases sprawl pressure on the city's periphery. Similar studies conducted by Sanches and Pellegrino (2016) concluded that promoting the use of vacant lands for UGS planning can assist planners, managers, and local authorities in decision-making to prioritize lands that initially were not considered, thus driving public and private investments with technical standards and supporting data.

Kabisch et al. (2016) assessed the availability of UGSs in European cities, emphasizing that this is a key component in navigating urban complexities as a means to improve human health and welfare. Our results also include an assessment of UGS availability within or in proximity to the selected UFZs. The analysis helped us to identify potential vacant land to be added in future UGI expansions. The results indicated that there is a balance between vacant land availability and existing land covered by UGSs in commercial and single-dwelling housing areas. The accuracy of the results referring to commercial areas is verified by the General Urbanization Regulations which bind retail developers to incorporate UGSs with a minimum of 2–5% of the land's area. However, the percentage of lands devoted to UGSs can be increased by local authorities through Local Urbanization Plans. This assessment also indicated that residential areas characterized by multi-dwelling housing are typically encircled by wide areas of UGSs. This is a remnant of the former socialist planning system that devoted an area of green space encircling each multi-dwelling structure. During socialism, green areas, and especially gardens, were considered a continuation of rural practices in an urban society, but post-socialism, they are an example of communal involvement (Borčić et al., 2016). Conversely, the locations of recorded agricultural and industrial areas show fewer areas devoted to UGSs, but also the widest available vacant land to be used as UGSs. These results are explained by the fact that industrial sites were planned on the outskirts of cities, surrounded by agricultural areas that later were abandoned (Grădinaru et al., 2015).

Studies have indicated that the presence of UGSs encourages development, especially of residential areas in closer proximity to a city center, which in turn affects the cost of housing (Panduro and Veie, 2013; Votsis, 2017). Therefore, a transformation of urban vacant land to UGSs will encourage reconversion of a derelict area into a positive urban environment and enhancing the compactness of a city.

## 5. Conclusion

The AHP model proves to be an efficient tool in assessing the potential

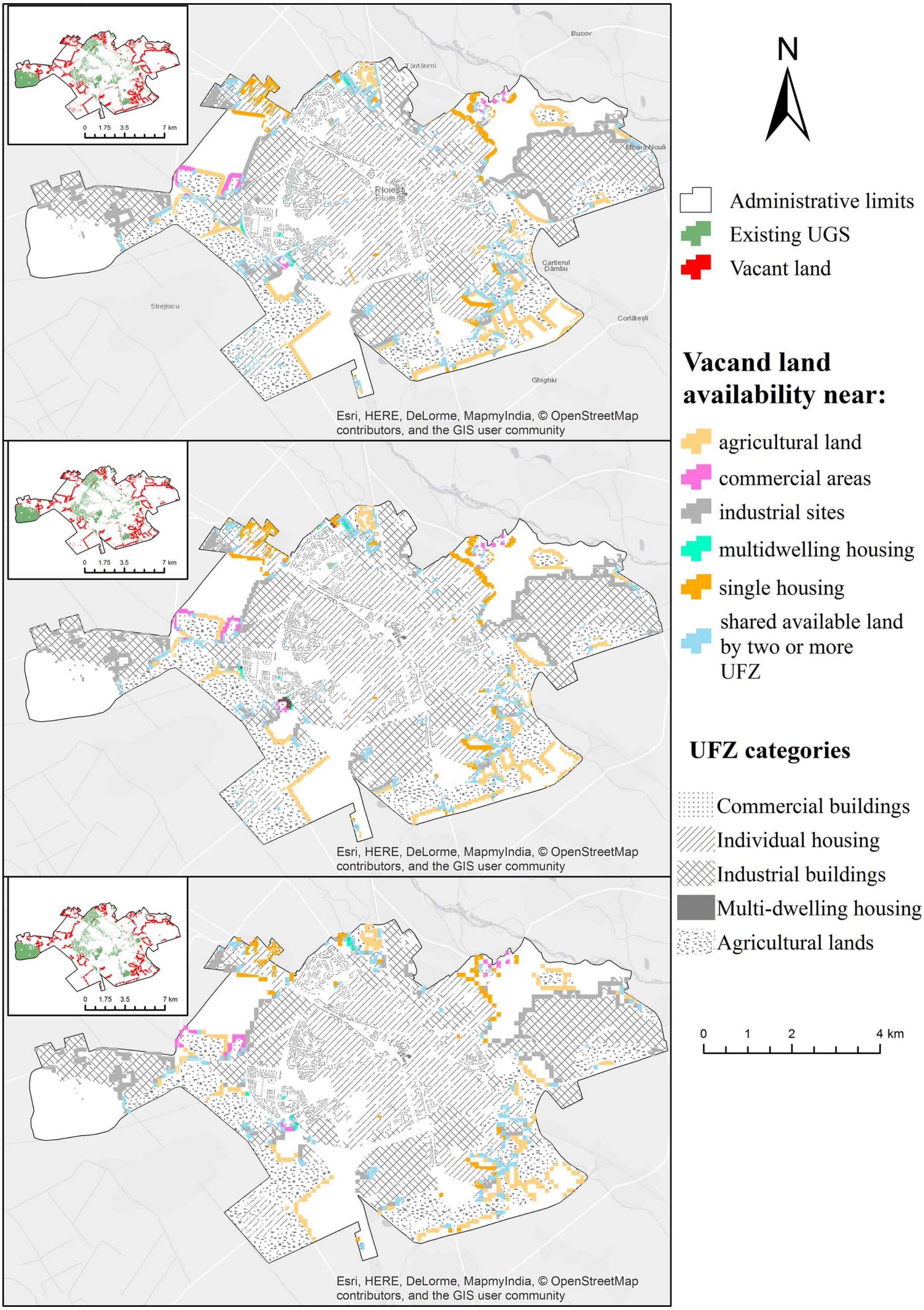
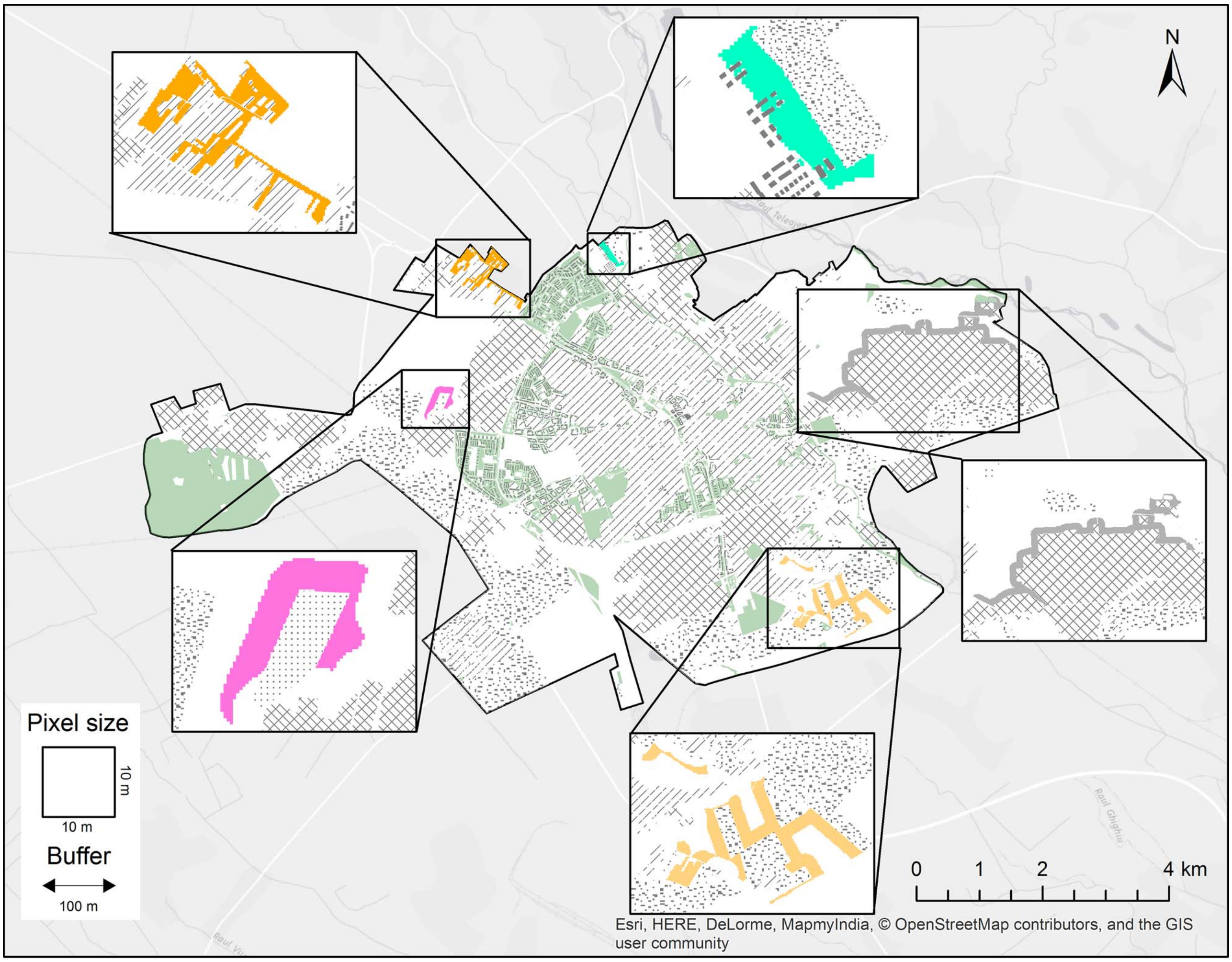



**Fig. 3.** The distribution of available land within the city limits.

of 27 UGSs in achieving nine selected criteria. It is a quantitative means to gauge the suitability of as site to be included in a UGI. A limitation of the approach is that AHP analysis is based on expert opinions, a subjective assessment. To improve our study, future analysis will include general population and stakeholder perspectives. The recommendation score assignments provided important results regarding the planning of new UGS in relation to the locations. Identifying available vacant land within the city limits is a major finding of this paper, as it confronts urban sprawl by




| Patch size (m$^2$) | Buffer (m) | Maximum homogenous area (ha) | | | | |
|---|---|---|---|---|---|---|
| | | Agricultural areas | Industrial areas | Commercial areas | Multi-dwelling housing | Single dwelling housing |
| ***100*** | ***10*** | 0.42 | 0.43 | 0.15 | 0.72 | 0.43 |
| | ***50*** | 18.14 | 29.30 | 4.80 | 4.16 | 19.26 |
| | ***100*** | 37.30 | 62.27 | 8.15 | 4.17 | 21.14 |
| ***2500*** | ***50*** | 5.29 | 11.88 | 1.38 | 5.16 | 9.25 |
| | ***100*** | 42.90 | 57.42 | 7.65 | 4.03 | 10.83 |
| ***10000*** | ***100*** | 16.90 | 23.52 | 6.00 | 2.54 | 6.45 |

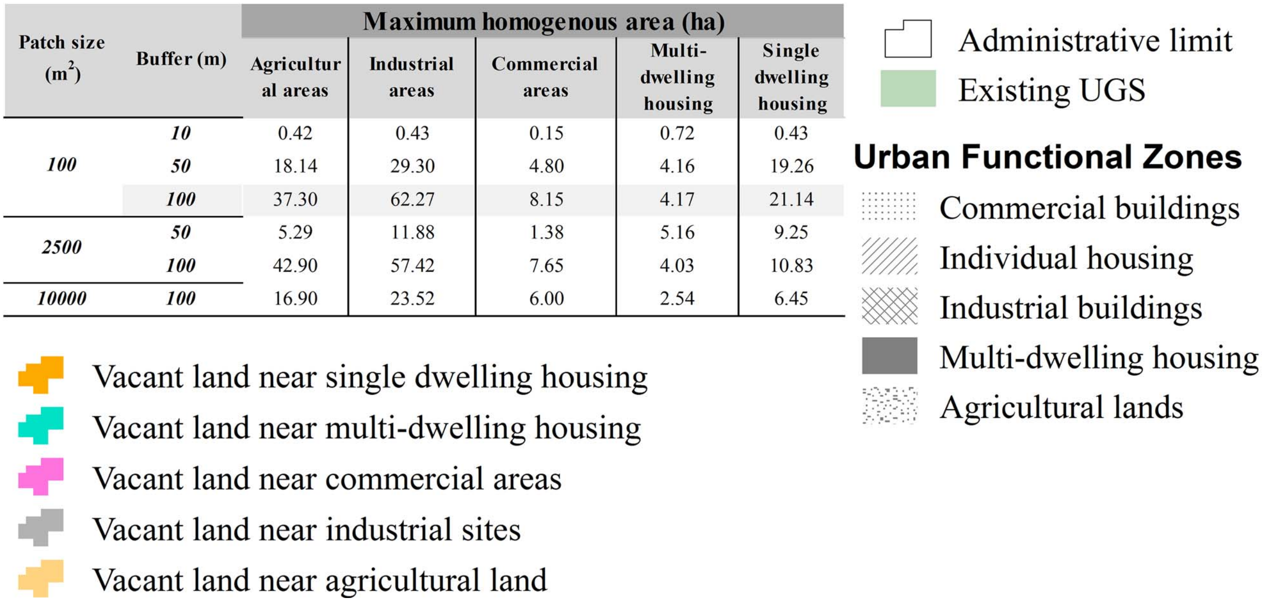



**Fig. 4.** Maximum homogenous land area distribution within the city limits and in relation to a UFZ.

providing spatial analysis of land availability that can be used for UGSs and development areas, promoting the compact city model.

The methodological framework proposed in this paper can be easily applied to any sprawling city with vacant lands within the city limits. The methodological framework proves to be an efficient approach in determining where and what new UGSs should be planned in relation to the particularities of the UFZs, fulfilling the intent of our study. Using Ploieşti as a case study we demonstrated that vacant lands could be considered a valuable commodity for dynamic urban development. A sustainable use of these lands could improve the quality of urban life

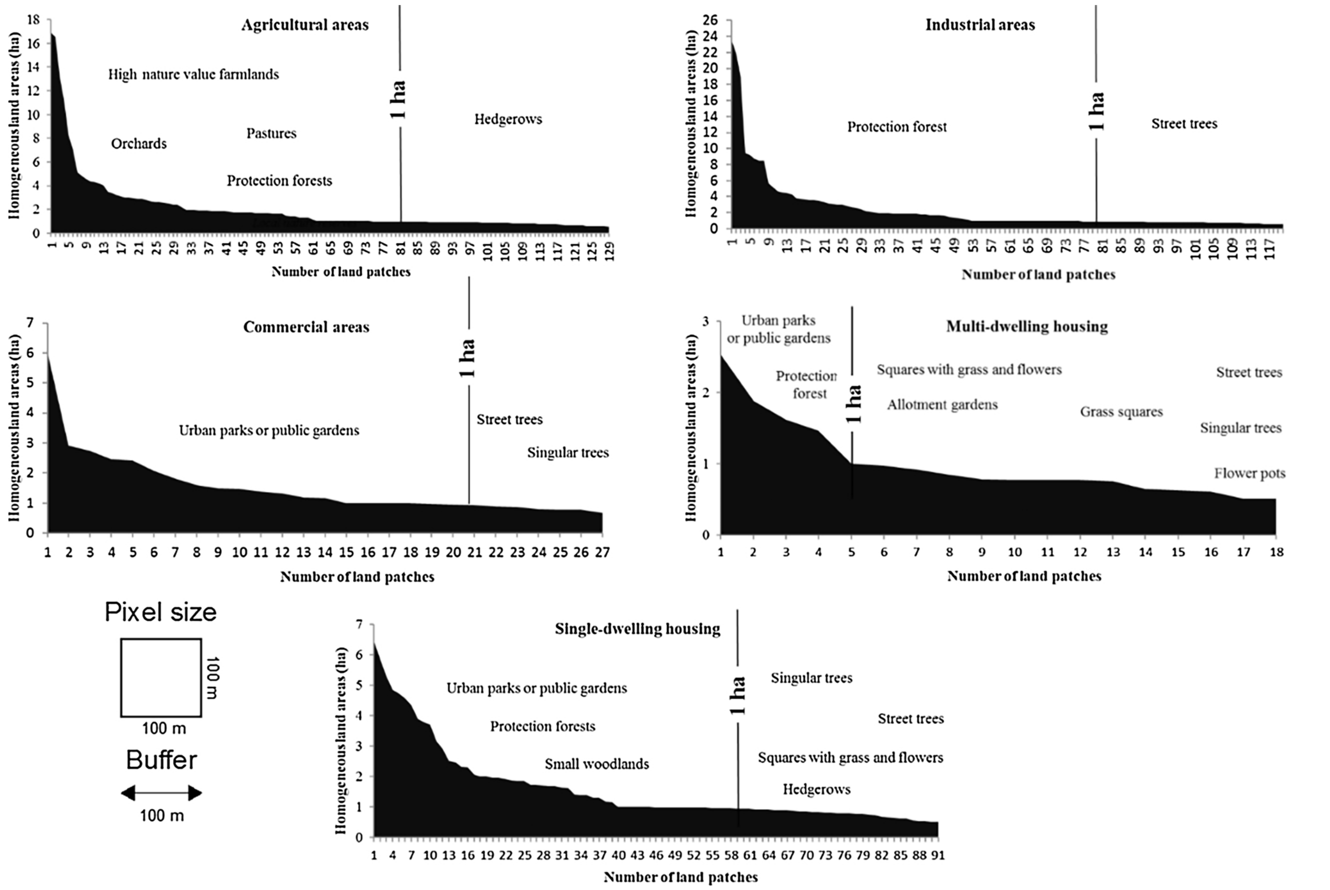



**Fig. 5.** Amount of available homogenous land patches in relation to the Rs for each UFZ.

and represent a benefit of the compact city model in any debate on urban sustainability.

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## Appendix A. Supplementary data

Supplementary data associated with this article can be found, in the online version, at http://dx.doi.org/10.1016/j.ecolind.2017.10.054.

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